PB85-116077

# Rationale and Basic Design for Experimental Acidification of a Lake Ecosystem in Northern Wisconsin

(U.S.) Environmental Research Lab.-Duluth, MN

Oct 84

U.S. Department of Commerce
National Technical Information Service
NTIS

PB85-116077
PB85-116077

EPA-600/D-84-254
October 1984

# RATIONALE AND BASIC DESIGN FOR EXPERIMENTAL ACIDIFICATION OF A LAKE ECOSYSTEM IN NORTHERN WISCONSIN

by

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**TECHNICAL REPORT DATA**
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| 1. REPORT NO. | 2. | 3. RECIPIENT'S ACCESSION NO. |
|---|---|---|
| EPA-600/D-84-254 | | PB85 116077 |

| 4. TITLE AND SUBTITLE | 5. REPORT DATE |
|---|---|
| Rationale and Basic Design for Experimental Acidification of a Lake Ecosystem in Northern Wisconsin | October 1984 |
| | 6. PERFORMING ORGANIZATION CODE |
| 7. AUTHOR(S) | 8. PERFORMING ORGANIZATION REPORT NO. |
| J. G. Eaton | |
| 9. PERFORMING ORGANIZATION NAME AND ADDRESS | 10. PROGRAM ELEMENT NO. |
| U.S. Environmental Protection Agency<br>Environmental Research Laboratory-Duluth<br>6201 Congdon Boulevard<br>Duluth, Minnesota 55804 | 11. CONTRACT/GRANT NO. |
| 12. SPONSORING AGENCY NAME AND ADDRESS | 13. TYPE OF REPORT AND PERIOD COVERED |
| Environmental Research Laboratory<br>Office of Research and Development<br>U.S. Environmental Protection Agency<br>Duluth, Minnesota 55804 | 14. SPONSORING AGENCY CODE<br>EPA-600/03 |

15. SUPPLEMENTARY NOTES

16. ABSTRACT

A multidisciplinary, integrated study of acidification of a 45-acre lake (Little Rock Lake) in Vilas Co., Wisconsin was begun on August 1, 1983. Two nearly-equal basins of the lake will be separated by a removable plastic barrier and one basin acidified while the other serves as a simultaneous reference or control. The basic experimental design consists of a two-year preacidification (baseline condition) study period, a 4-year incremental acidification phase, and a one or more year recovery phase. The study is being accomplished through cooperative agreement between the U.S. EPA Environmental Research Laboratory in Duluth and four area universities, the U.S. Geological Survey and the Wisconsin DNR. The results are expected to provide information important to obtaining key objectives of the 1982 National Acid Precipitation Assessment Program (NAPAP) Operating Research Plan related to predicting effects of acid precipitation on aquatic ecosystems.

17. KEY WORDS AND DOCUMENT ANALYSIS

| a. DESCRIPTORS | b. IDENTIFIERS/OPEN ENDED TERMS | c. COSATI Field/Group |
|---|---|---|
| | | |

| 18. DISTRIBUTION STATEMENT | 19. SECURITY CLASS *(This Report)* | 21. NO. OF PAGES |
|---|---|---|
| Release to public | Unclassified | 10 |
| | 20. SECURITY CLASS *(This page)* | 22. PRICE |
| | Unclassified | |

# RATIONALE AND BASIC DESIGN FOR EXPERIMENTAL ACIDIFICATION OF A LAKE ECOSYSTEM IN NORTHERN WISCONSIN

Task Group Project: E03-07

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## ABSTRACT

A multidisciplinary, integrated study of acidification of a 45-acre lake (Little Rock Lake) in Vilas Co., Wisconsin was begun on August 1, 1983. Two nearly-equal basins of the lake will be separated by a removable plastic barrier and one basin acidified while the other serves as a simultaneous reference or control. The basic experimental design consists of a two-year preacidification (baseline condition) study period, a 4-year incremental acidification phase, and a one or more year recovery phase. The study is being accomplished through cooperative agreement between the U.S. EPA Environmental Research Laboratory in Duluth and four area universities, the U.S. Geological Survey and the Wisconsin DNR. The results are expected to provide information important to obtaining key objectives of the 1982 National Acid Precipitation Assessment Program (NAPAP) Operating Research Plan related to predicting effects of acid precipitation on aquatic ecosystems.

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## IMPORTANCE

The overall objective of this study is to achieve as close to a whole ecosystem understanding as possible of the effects of anthropogenic acidification of a lake, and therefore of why things change the way they do. Such mechanistic knowledge permits much more precise and confident prediction of biological or water chemistry effects based on projected loadings of acid precipitants. To accomplish this a multidisciplinary research effort, involving skills in the areas of fish population dynamics, aquatic ecology, limnology, geology, toxicology, etc., is required.

The decision to conduct a system acidification experiment was made in 1982 following a significant expansion in the aquatic biological effects research program in Duluth. There are basically three research-type options from which biological effect information can be obtained: 1) lab studies (chronic and acute bioassays, physiological tests, etc.); 2) field biological surveys across presumably directly responsible acid deposition gradients; and 3) whole system or more limited scale (e.g., enclosures) field experiments. Each of these has its pros and cons: lab studies -- maximum control of extraneous variables but some uncertainty in extrapolating results to whole ecosystems; field surveys -- opportunity to observe intact ecosystem conditions but usually poor background (starting point) information and the possibility of extraneous perturbants (e.g., resource management manipulations, other pollutants, etc.); and field acidification experiments -- accurate background and/or simultaneous reference information and observance of intact ecosystem responses, but usually not entirely realistic acidification mechanisms (e.g., addition of acid only to water instead of a whole watershed) and more rapid pH change than occurs naturally. It probably goes without saying that all of these provide complimentary and necessary kinds of information. However, it appeared that a whole system acidification study would provide the greatest amount and diversity of unequivocal biological effects data. An international NAPAP sponsored workshop held in the fall of 1982 to define biological research needs and to recommend data acquisition strategies also recognized the exceptional utility of system acidification projects (1). In fact, data on 8 of the 12 major research objectives listed by the workshop participants will be generated during the lake acidification study, something not possible from lab studies and not economically feasible from surveys.

Questions have been raised about the rationale for conducting such an investigation in an area of low current, and possibly future, acid precipitation biological effects impact. Yet this uneffected state in combination with extreme sensitivity provides an especially good opportunity for observing the earliest, most subtle changes resulting from system acidification. Such a pristine condition was a major factor in the selection by the Canadians of the ELA as an acid precipitation research area (Dr. David Schindler, personal communication). A particular lack of data on the effects of acidification on warm-water fish and systems, which are found in sensitive water bodies in many areas of the U.S. and Canada, including the Adirondacks, has been pointed out (2,3). There are also sensitive seepage lakes in other regions of the U.S. that receive higher acid rain loadings. In attempting to satisfy the Aquatic Effects Task Group objective of achieving a nationally applicable predictive modeling capability by 1989, it seems important that the developmental, parameterization and validation information comes from as diverse an array of sensitive ecotypes as possible, and therefore that it not all be generated in the Eastern U.S. or in trout waters. By the end of the first phase of the experiment, just before acidification commences, we intend to formulate and unchangably record our best guesses and hypotheses about the effects of acidification on the lake ecosystem at each successive stage of the acidification process. Comparing these estimates with what actually happens will provide a rigorous test of our current prediction capabilities, help define subsequent research needs, and indicate how close we are to achieving the Aquatic Effects Task Group primary objective of developing such a capability by 1989.

There are two additional, more parochial reasons for conducting the study where it is. One concerns the large number of relatable investigations underway in the same area by several other groups--National Acid Deposition Monitoring Program, Electric Power Research Institute, Wisconsin Department of Natural Resources, U.S. Geological Survey, etc. Information from these studies, some obtained at Little Rock Lake itself, will increase the utility of our data and vice-versa. Of particular significance is the suite of 7 area lakes being intensively monitored both biologically and chemically through the University of Wisconsin Northern Highlands Long Term Ecological Research Program. By making the same measurements in the test lake as in the LTER lakes, the ability to discern acidification effects, and to determine their extrapolatability to other water bodies is greatly enhanced. A nearby NADP site (4 miles away) will provide useful precipitation chemistry information. The second reason is that a lake with the desired characteristics was found over which exclusive control was obtained for the duration of a long term study. Considering all of the above reasons for conducting the study in northern Wisconsin, it is unlikely that many equally favorable sets of circumstances could be located elsewhere in the U.S.

## HYPOTHESES

(1) There will be no biological changes in the test lake as it is gradually acidified from a pH of 6.0 to about 4.5.

(2) There are no differences between the responses of organisms, or oganism-mediated processes, in an acid-sensitive warmwater seepage lake and the responses of corresponding taxa or processes in other lakes that have been studied in different geographic areas, or that have different water chemistry, geological substrate, climatological, or biological characteristics.

(3) In natural waters, there is no greater toxicity to fishes than that caused by water chemistry alone, regardless of any other effects that might be occurring in the ecosystem in question (i.e., indirect or secondary effects, such as food chain disruption, are unimportant in evaluating potential effects on fish).

(4) Assuming the exposure (water quality) conditions are comparable, the responses of aquatic organisms are identical in laboratory toxicity tests and in field exposures to acid conditions (i.e., all the required aquatic effects information for many organisms can be obtained from lab tests; no field testing is required).

(5) There will be no differences between what is predicted will happen to organism populations and functional processes in Little Rock Lake and what will have been observed by the end of the study (i.e., we already possess enough knowledge to accurately predict or model aquatic ecosystem impacts of acidification).

(6) Additional, more specific hypotheses are proposed in the summaries of Principal Investigators.

## TECHNICAL APPROACH

The project is primarily extramural and is being supported through cooperative agreements between EPA and the Wisconsin Department of Natural Resources, the U.S. Geological Survey, the University of Minnesota, the University of Wisconsin, and the University of Wisconsin-Superior. The 45 acre study lake is situated on state-owned land, is devoid of human habitation, and has 2 approximately equal basins connected by a central narrows. A recently enacted state law has granted the participants legal permission to control access to the lake and to modify its natural characteristics for the duration of the study or approximately 10 years. A Dacron®-fiber reinforced PVC plastic barrier has been placed across the constriction between the 2 basins, one of which will be gradually acidified while the other serves as a simultaneous reference or control basin.

The lake, named Little Rock Lake, is located in Vilas County, Wisconsin on thick deposits of glacial drift containing small amounts of calcium and magnesium (1-2 meq/100 g), low cation exchange capacity (~10 meg/100 g), and low base saturation (10-30%) (4). The area is heavily forested and exhibits a dense concentration of small-to-medium sized lakes with characteristics similar to LIttle Rock. This one and

many of the other lakes have a seepage hydrology with no surface water stream inlets or outlet, water influx occurring either from ground water or by direct precipitation. The Little Rock Lake watershed is near the top of the regional ground water table and is only about 4 times the lake surface area, so precipitation dominates water inflows and there is a net discharge to the substrate. Water in the lake is very soft and poorly buffered (25 μeq/l alkalinity). It is slightly acid (pH 6.0) and clear, not a bog lake. Analyses using acid precipitation loading information and historical water quality data seem to indicate there has been little if any effect on the pH of the more sensitive lakes in the area, although impact evaluations are continuing. The lake's fish populations, consisting chiefly of largemouth bass, rockbass, and perch, are representative of those found in many acid-sensitive warm water lakes, as are the plants and animals of lower trophic levels in the lake.

The experimental plan entails two years of preacidification study of the lake (1983 and 1984), approximately four years of gradual acidification (1985-1988), and approximately one year of recovery (1989). The various individual research activities must be complimentary and coordinated; a study site manager has been hired to assist this process. The Duluth lab is also conducting laboratory bioassays using simulated Little Rock Lake water to more clearly define relationships between toxicity and water constituents, and between lab and field results. Investigations at the lake consist of two types: 1) chemical and biological "site general" analyses which provide basic data required by and available to all participants, and 2) more detailed and mechanistic studies of effects on specific components or processes.

The preacidification phase has several specific objectives which include: 1) generation of two years of baseline information for obvious comparison purposes; 2) to conduct experiments in 10 littoral limnocorrals (4 M diameter x 2 M deep) and 2 pelagic limnocorrals (4 M diameter x 5 M deep) for the purposes of refining test hypotheses and therefore sharpening the focus of investigations during the whole-basin acidification phase, and for further defining the experimental conditions to be imposed during the acidification phase (kind of acid, rate of pH change, etc.); and 3) to conduct experiments not possible in the whole-basin treatment (e.g., exposure to different or a wider range of treatment conditions, observation of responses in the absence of certain system components such as fishes, etc.). The curtain dividing the two basins was installed at the end of the first year (August 1984) and its effects will be studied for a second complete year prior to acidification to determine any possible effects on fish populations and operational characteristics.

Phase 2, acidification, will take place over several years with the final design being determined on the basis of all results obtained up until the time of each successive decision point. Enclosure studies will continue during this test phase related to evaluation of an expanded range of treatment or exposure circumstances.

The design of the final or recovery phase is uncertain at this time. EPA, through its agreement with the Wisconsin Department of Natural Resources, is responsible for returning the lake to pretest conditions, but the state of the knowledge of mitigation techniques or effects may well determine how this is accomplished, how long it takes, and the resources involved.

RESULTS, DISCUSSION and CONCLUSIONS are in most cases preliminary and will be described by the Cooperative Agreement Principal Investigators in the presentations (Research Summaries) that follow.

## REFERENCES


1. Baker, J., Research Priorities for Assessment of Impacts of Acidic Deposition on Aquatic Biota: A Workshop Report. U.S.E.P.A./North Carolina State University Acid Precipitation Program. Raleigh, N.C. Nov. 1982.

2. Pfeiffer, M. H., and Festa, P. J., Acidity Status of Lakes in the Adirondack Region of New York in Relation to Fish Resources. N.Y. State Dept. Environ. Conservat. Aug. 1980.

3. Preddice, T. L., Senior Aquatic Bilogist, N.Y. State Dept. Environ. Conservat., Personal Communication.

4. Eilers, J. M., Glass, G. E., Webster, K. E., and Rogalla, J. A., Can. J. Fish. Aquat. Sci., 40: 1896 (1983).

5. Schindler, D. W., Can. J. Fish. Aquat. Sci., 37: 313 (1980).


## DELIVERABLES

(1) Cooperative Agreement final reports from Principal Investigators at termination of current project period, March 31, 1985, and at termination of the subsequent project period, March 31, 1988.

(2) Summary presentations and publications of research activities.

## RELATIONSHIP TO OTHER WORK

Demonstration of the utility of whole-system acidification has come largely from several lake manipulations conducted during the past 15 years at the Experimental Lakes Area (operated by the Canadian Department of Fisheries and Oceans) near Kenora, Ontario (5). The explanation value of the ELA studies has received world-wide recognition. Scientists there have been very supportive of the idea of a similar study in northern Wisconsin and have worked closely with us in its design. The Canadians are especially interested in comparing their observations in granitic bedrock, cold water (lake

trout) lakes to our warm water, glacial drift substrate results. Effects on Little Rock Lake will also be related to observations obtained in many other field surveys, laboratory toxicity tests and field experimental manipulations.

The work at Little Rock Lake will investigate aspects of the research objectives listed by Aquatic Effects Task Group E-02 (determine and quantify the critical biogeochemical processes that modify acid deposition and determine the chemistry of receiving waters), Task Group E-04 (evaluate the effects of deposition-caused acidification on the accumulation of toxic materials by fish and wildlife in high deposition areas) and Task Group E-05 (conduct field and laboratory tests to determine chemical and biological effects of liming and other mitigation techniques for lakes and streams). Three of the five E-03 Task Group objectives (related to predicting biological effects) will be investigated, and a second lake artificial acidification experiment is being planned for the Eastern U.S. to complement the one in Wisconsin. Inputs from Task Group E-01 (Sensitive Systems) research projects, NADP reports, and state agency reports have been invaluable in the process of selecting field research sites. Several additional relationships to other projects or findings are described in preceeding sections.

## ACTIVITIES

Eaton, J. G., J. H. McCormick, P. Brezonik, J. Perry, J. Eilers, T. Sheffy, W. Rose, T. Kratz, J. Magnuson, T. Frost, and W. Swenson. 1983. Warmwater lake community responses to artificial acidification. Proceedings, Technical Conference on Acid Deposition and Aquatic Resources in the Upper Midwest. October 25-27, LaCrosse, Wisconsin. North Carolina State University Acid Deposition Program. Abstract.

Eaton, J. G. Experimental acidification of a lake ecosystem in northern Wisconsin: rationale, design and preliminary findings. 1984. Proceedings, Technical Association of the Pulp and Paper Industry Research and Development Conf. Sept. 30 - Oct. 3, Appleton, Wisconsin. 7 pp.

## SUPPORT

University of Wisconsin-Superior - $12,867, 1983-85;
University of Minnesota-Duluth - $3,741, 1983-85;
University of Wisconsin - $11,292, 1983-85;
Wisconsin Department of Natural Resources - $8,462, 1983-85;
U.S. Geological Survey - $52,300, 1983-85;
University of Minnesota - $20,810, 1983-85;
EPA - $690,830, 1983-85.

## PERSONNEL

U.S. EPA Acid Deposition Effects Program Manager - Dr. Raymond D. Wilhour. Corvallis, Oregon.

NCSU/EPA Biological Effects Program Research Manager - Dr. Joan P. Baker. Raleigh, N.C.

U.S. EPA Lake and Stream Acidification Program Research Manager - Dr. Robbins Church.

U.S. EPA Duluth Acid Deposition Biological Effects Research Program Manager - John G. Eaton

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